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CODES AND CONTROLS IN LIVING CELLS

CAPTAIN B. D. STOLLAR, USAF (MC) AFOSR

Living cells contain an amazing assembly of chemical machinery which utilizes, transforms, stores and releases energy for all life processes. A great deal of scientific energy has been devoted in recent years to studying how this machinery is built, and what turns it on and off, regulates its rate of operation, and coordinates the activities of its thousands of parts.

The machinery, responsible for building and maintaining all cell structures, consists of enzymes, which are proteins with specific catalytic properties. They allow complex chemical reactions to occur under the mild conditions of physiological temperature, pH, and pressure. Each enzyme catalyzes one or a few specific reactions. This specificity depends on the enzyme structure, which in turn depends on the arrangement of building blocks which make up the enzyme. About 20 such building blocks, or amino acids, occur naturally in proteins. In varying sequences in long chains, they can take up an enormous number of different sizes and shapes, the possibilities being multiplied by secondary and tertiary folding of the primary chain.

The information directing the building of enzyme molecules is contained in other large molecules, deoxyribonucleic acid (DNA). There are four kinds of basic building blocks, or nucleotides, in DNA, and upwards of 20,000 nucleotides in each of about 1,000 DNA molecules in an animal cell. The sequence of the four nucleotides in DNA encodes the sequence of amino acids in proteins. DNA itself remains inside the nucleus of the cell and sends a "messenger", ribonucleic acid (RNA), to the protein building sites; the sequence of nucleotides in RNA is complementary to that in DNA, and is translated into amino acid sequence in proteins. The

sum of all the information and building thus transmitted makes up the very nature of the cell and eventually of the whole organism. The RNA code has been intensively studied and partially deciphered in recent years, in one of biochemistry's most exciting studies.

It is apparent that the information encoded in DNA is thus basic to the total operation of the cell, even to building new DNA to pass on from generation to generation. Dr. J. Marmur, of Brandeis University, with the help of an AFOSR grant, will continue important studies he had made in comparing the structure and nucleotide sequences of DNA extracted from a variety of plant, animal, bacterial and viral sources.

The DNA molecule, however, is more than a template encoding protein structure. Not all of its information is being read and utilized at any one time; therefore, DNA must also contain mechanisms to control the timing and rate of synthesis of specific enzymes. For example, the accumulation of an excessive amount of a product of an enzymatic reaction may turn off enzyme activity, or can interact with DNA to slow down synthesis of the enzyme; these are feedback controls.

Another type of control exists in certain bacteria which have the information for building an enzyme to split a chain of sugars, ((A^B) for example), into its simpler parts (A and B), which can be used by the bacteria. If the organism grows where there is no A^B, it does not make appreciable amounts of the enzyme to split the chain. However, if A^B is added to the growth medium, the enzyme is produced in large amounts. This process is termed induction of enzyme synthesis. H. O. Halvorson (University of Wisconsin, AFOSR grantee) has been studying such a control mechanism in yeast, and has located the site where the new enzyme is synthesized. Further, with genetic studies, the role of a complex interaction of A^B with DNA in turning on the synthesis is being determined.

A technique useful for studying these control mechanisms is being used by several investigators, including Dr. Halvorson and Dr. B. Nisman in Paris, (AFOSR grantee). It has become possible to break cells down into components, and to recombine selected components under conditions allowing protein synthesis outside the living cell. A few laboratories, including that of Nisman, have reported synthesis of specific enzymes under similar selected conditions. In such a system, the role of various cell components in the process of induced enzyme synthesis can be studied. It has been learned that DNA does play an indispensible role. The same technique will be applied by Dr. J. R. Fisher at the Florida State University, under an AFOSR grant, in studying the onset of synthesis of a specific enzyme at a regular time during embryonic development of chicks.

Studies on mechanisms controlling enzyme synthesis and functions have brought biochemists, geneticists, and biophysicists together in probing a most remarkable information storage, transmission and utilization system. A fuller understanding of such mechanisms may well allow a greater measure of control of numerous biological processes, of problems of development and aging, and of certain diseases. Furthermore, fuller knowledge about such complex communication and control systems may lead to generalized principles which could have important implications in man-made devices which face similar problems.

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In describing the motion of a particle of negligible mass traveling from the vicinity of a massive celestial body to a much smaller body (say earth to moon) it has been commonly accepted that a crude first approximation could be made by patching two Keplerian conics appropriate to the motions in the vicinity of the individual bodies.

Working under an AFOSR grant at California Institute of Technology, Drs. Lagerstrom and Kevorkian have re-examined this intuitive idea from the point of view of deriving a uniformly valid asymptotic approximation for the solution, applying the methods of singular perturbation theory. Their results were presented at the November 1962 meeting of the American Rocket Society.

It is shown that there is no mathematical justification for the direct patching of conics, and that a higher approximation to the motion for the initial leg must be used in order to derive a really useful approximate description for the entire motion.

Consider the restricted three body problem, and let the mass μ of one gravitation center (the "moon") be much smaller than that of the other center (the "earth") which has mass $1-\mu$. Approximation to the motion of a particle moving under the influence of these two centers may be obtained by developing the solutions in powers of μ.

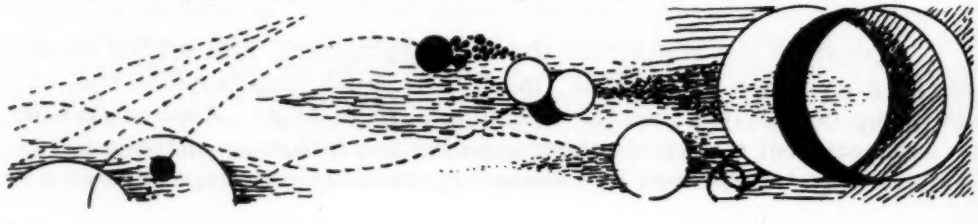
The influence of the moon then appears as a correction of order μ to a motion which is Keplerian relative to the earth. This scheme fails when the particle is in a region sufficiently close to the moon for the field of the moon to be dominant. As Kevorkian found previously, the motion in this region is, to first order, Keplerian relative to the moon. To study this motion, "blown up" coordinates are used, i.e., distance to the moon and time are measured in units which are suitable powers of μ.

For trajectories which leave the earth, approach, and are influenced by, the moon, and upon leaving it's vicinity again are dominated by the earth's gravitational field, it is shown that to first approximation, the moon's effect is represented by a discontinuity of the slope of the orbit at the lunar location. The magnitude of this discontinuity depends upon the angular momentum of the hyperbolic orbit associated with the moon. Since this angular momentum depends strongly upon the distance of lunar approach (which is of order μ), it is impossible to locate the correct orbit in the one parameter family of possibilities unless the solution for the approach leg is carried out to order μ.

Thus, the composite solution which uniformly approximates the exact complete motion must include a first correction to the Keplerian orbit for the approach leg.

For the purpose of illustrating these basic ideas, it is sufficient to consider the simple problem of two fixed force centers, since the crucial questions of approximation and matching procedures hinge on the nature of the gravitational terms and do not depend on the fact that these centers rotate.

Actually, the problem of two fixed centers may be solved in principle by quadratures since two invariants are known. However, instead of starting from the integral representation which formally gives the exact solution, perturbation methods are used which proceed from the differential equations and hence apply to the restricted three body problem for which only one invariant is known.



AFCRL PARTIPATION IN IQSY

Publications & Information Office (AFCRL)

AFCRL plans strong participation in the International Quiet Solar Year (IQSY) during the 1964-1965 period. The IQSY represents a concentrated and coordinated program of scientists all over the world for the observation of solar and solar-induced activities during the quiet period of the sun's 11-year active-quiescent cycle.

Two AFCRL scientists have been named by Assistant Secretary of the Air Force for R & D, Brockway McMillan, to serve on the U.S. Committee for the IQSY. They are Christos G. Stergis and Wolfgang Pfister. A special working group of 16 scientists for the IQSY has been established within AFCRL for the prupose of formulating a program to be conducted in concert with other U.S. and foreign scientists.

AFCRL programs are planned in the fields of meteorology, geomagnetism, aurora and airglow, ionospheric physics, cosmic rays, solar activity and aeronomy. A large percentage of the IQSY program will rely on established or previously scheduled programs conducted by those agencies and laboratories concerned with research in geophysics and related phenomena. The National Science Foundation will review these proposed programs and will consider the possibility of funding them.

The scientific objectives of the IQSY program fall into three major categories: 1) Studies which are feasible only or are best undertaken at the time of minimum solar activity; 2) Studies of isolated solar events which are not complicated by the super-position in time of many different effects; and 3) Comparison of data characterizing minimum solar activity with those referring to solar maximum.

The AFCRL IQSY Working Group will forward its plans to OAR which in turn will forward them through the USAF and U.S. Committee for the IQSY channels to the International Council of Scientific Unions. The IQSY is managed in much the same manner as the highly success-

ful IGY, a program which saw AFCRL participation in 12 of the 13 major areas of IGY study.

Chairman of the AFCRL Working Group is Major Thomas Douthit. AFCRL members and their field of interest are:

Meteorology: Robert Leviton, Major Robert Lenhard, John Wright, Wayne S. Hering, and Ralph Shapiro; Geomagnetism: Robert Hutchinson, Bert Shuman, and Edwin Chernosky; Aurora and Airglow: Thomas Markham; Ionospheric Physics: Wolfgang Pfister, James Ulwick, Thomas Keneshea, Philip Newman; Cosmic Rays: Lou Katz; Solar Activity: Jack Evans; Aeronomy: Chris Stergis, Bob Rosenberg, and Jules Aarons, and Rockets: R. M. Slavin.

transmitter substance and osmotic *EQUILIBRIUM*

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Directorate of Life Sciences (AFOSR)

The peripheral nerves, those running from the brain or the spinal cord, to other parts of the body, fall into two major groups. The somatic nerves run to muscles which are under voluntary control. The other group is made up of the autonomic fibers. These supply the heart, all glands and all smooth muscle, such as that in the intestine.

In this report we want to talk about the autonomic side. The autonomic fibers fall into two further groups: sympathetic and parasympathetic. Most tissues receive nerves from both of these divisions. The effects of stimulating the two divisions are usually diametrically opposite. How stimulation of different nerves on the same organ can produce opposite effects was a mystery for many years. The explanation is simple.

At the end of the nerve fibers of the parasympathetic system, acetylcholine is released upon nervous activity; in the sympathetic nervous system, two chemical substances are released at the nerve

endings; Nonadrenaline and adrenaline. These substances, the transmitter substances, move to the tissues involved and chemically alter their activity. As an example, adrenaline released in the heart increases the rate and force of the beats.

Examination of the endings of the nerves has revealed granules which are postulated to be the source of the chemical transmitters. Dr. U.S. von Euler, of Karolinska Institute, Stockholm, Sweden, working partly under a grant from the Air Force Office of Scientific Research, AF EOAR 62-14, has studied the role of the granules in the production, release, and recovery of the transmitter substances. He finds that on the average, an equilibrium exists between the transmitter substance in the granules and in a surrounding solution. In a buffer at neutral pH, in a density gradient ultracentrifugal field, the granules will take up transmitter substance from a surrounding solution containing more than 10 μg per ml. of the substance. They release the material if its concentration in the solution is less than this. At the concentration of 10 μg. per ml., no net uptake or release is observed. Hence, von Euler thinks that release or uptake of adrenaline is determined by diffusion gradients.

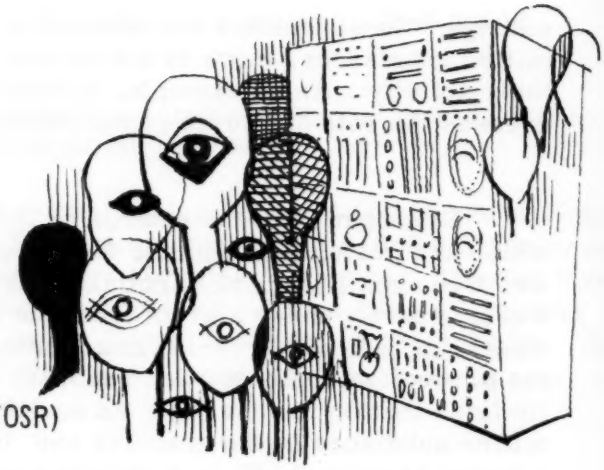
Upon stimulation of sympathetic nerves, increased permability occurs, leading to loss of adrenaline from the nerve protoplasm into the surrounding tissues. This loss is promptly made good from the stores in the granules. Upon cessation of stimulation, the gradients are reversed and transmitter substances free in the tissues promptly move back via nerve, to the granules.

There are two sizes of granules present, some 500 to 2000 Angstroms and others about 200 Angstroms in diameter. More work is needed to clarify the nature of these granules and some of the controls which operate upon them to increase or decrease their transmitter content.

Going back to the other division of the autonomic system the parasymphathetic, the transmitter substance is acetylcholine. Its formation and control are much like that of the two transmitters above, but adequate discussion of this substance is beyond the scope of this brief review.

CYCLOPS and COMPUTERS

ROWENA SWANSON
Information Research Division, (AFOSR)



"In the country of the blind, the one-eyed man is king". An analogy is inferrable among modern-day nations of men who work with their hands and intellects, where the man with a machine may be king. May be, if the machine is specific for the competing function and is properly used.

It is the contention of Dr. Douglas C. Engelbart of Stanford Research Institute, Menlo Park, California, that the intellectual capacity of man can be aided by appropriate combinations of artifacts, methodology, and training. These he calls augmentation means which, together with man, comprise an H-LAM/T system (Human using Language, Artifacts, and Methodology, in which he is Trained). Under AFOSR contract AF 49(638)-1024, Dr. Engelbart has been conducting a search for a conceptual framework within which a coordinated research and development program could be established (a) to determine the factors which limit the individual's basic information-handling capabilities for problem solving, and (b) to develop new techniques, procedures, and systems for the better use of these capabilities. His hypotheses and suggestions are incorporated in a recent report, AFOSR-3223, "Augmenting Human Intelligence".

Dr. Engelbart provides a preview of a hypothetical approach to problem solving via a description of the way "Joe", a trained and experienced user of an augmentation system within an experimental research program, might go about his work. Joe is equipped with two display screens connected to a computer, a light pen for changing the displays, and a keyboard. The keyboard and the light pen are his most

frequently used tools in his efforts to arrive at solutions, or procedures toward solutions, of his problems. He is able, via the keyboard, to put information into the computer and to call information from storage. He modifies the displayed information with the light-pen. His language is a mixture of symbols specifically formulated to express, in intelligible shorthand, the concepts he manipulates. The data he needs from prior work are all in storage, subject to immediate recall. Effects of changes in any parameter on the solution or a part of the solution are immediately determined through light-pen adjustment of the displays. He can get statistical predictions, develop structured concepts of thought, design a process sequence, or evaluate a planned manuever, within very brief periods of time, without leaving his workplace or calling on aides.

Historical antecedents of the work of Dr. Engelbart and others stem in large part from the prodigious expansion in research and development during and since the World War II period. Mountains of information, the need for quick (but accurate) decisions, and a growing technology of comparatively inexpensive devices (photocells, thermionic and cathode-ray tubes) seem to provide both the source of the problem and means toward its solution. Support of research toward solutions of the information morass was fostered by such prominent scientists a s Vannevar Bush and John von Neumann. In the Atlantic Monthly of July, 1945, Dr. Bush wrote: "(Man) has built a civilization so complex that he needs to mechanize his records more fully if he is to push his experiment to its logical conclusion and not merely become bogged down part way there by overtaxing his limited memory. His excursions may be more enjoyable if he can reacquire the privilege of forgetting the manifold things he does not need to have immediately at hand, with some assurance that he can find them again if they prove important" (p. 108).

Dr. Engelbart reports on some of the languages and techniques which have been developed for modeling complex processes and systems, and for incorporating "intelligence" into machines which have accompanied an advancing computer technology. He reviews the componentry which is available now and can be combined with "software" in studies to determine optimal man-machine relationships. His conjecture that such combinations would be synergistic is supported by the assistance man has already derived from computer and other machine processing of commercial and scientific data. He describes a possible program for studying, from a total-system standpoint, the performance of man plus augmentation means in the conduct of a task in which effectiveness could be measured at the various stages of deriving, testing, and in-

tegrating innovations into the system.

Dr. Engelbart contends that the development of powerful and economic augmentation systems is possible with present knowledge and technology. Future knowledge of thought, learning, and memory processes and the logical designs for mechanically simulating these processes can be incorporated into what will then be known about augmentation systems. Augmentation systems could possibly be used in the advancement of such knowledge - a boot-strapping situation. Appropriately designed networks of servomechanisms to man could soon become the only modii operandi by which man will be able to function efficiently and effectively. It is toward these objectives that Dr. Engelbart's efforts and the investigations of others into human mental and physiological processes, patterns of logic and the organization of information, and means of communication and symbolic structuring are directed.

plasma arc seminar at ARL

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"Too many meetings" and "too many papers" are frequent comments in technical groups. Yet, the real complaint is probably that meetings are too diverse, and one encounters too many papers outside of his immediate field of interest. During a symposium on plasma jet technology, organized by A.S.M.E. Committee K-6, "Experimental Techniques in Heat Transfer", it was suggested that a national meeting on the same subject be organized under guidance of personnel of the Thermo-Mechanics Research Laboratory of the ARL, for investigators doing research in this field. The idea found enthusiastic backing. However, after correspondence with interested ARL contractors, it was decided to start with a small scale meeting involving only ARL contractors and representatives of interested Government agencies.

In order to coordinate all these efforts, and to give research personnel a forum for personal contacts and exchange of opinions, a 3-day seminar on plasma arc research was held 17-19 September 1962 at ARL. One purpose of the meeting was to serve as a trial balloon for large meetings which are anticipated in the future. Attendance was by invitation, and was limited primarily to ARL contractors and to other Government activities having technical interests in arc research. Twenty-four informal

presentations were made, and ample time was allowed for discussions. The highlight of the seminar was provided by a guest lecturer, Professor Dr. Gunter Ecker, of the Institute of Theoretical Physics, University of Bonn, Germany, whose topic was, "Electrode Components of Arc Discharge". Dr. Ecker's lecture, and the other technical presenta ons, will be assembled and published as an ARL report early in 1963.

Because of the enthusiastic participation of the attendees, and the favorable comments received after the meetings, a plasma arc seminar will probably be repeated annually. It is expected that attendance will become progressively larger, but every effort will be made to stay within the bounds of a limited scientific area discussed by active investigators.

ARL interest in electric arcs stems from the fact that electric arcs provide a simple means of heating continuous gas streams to temperatures higher than attainable by other presently available heating methods. Such gas streams, or plasma jets, are essential to Air Force applications involving electro-thermal space propulsion, and the simulation of hyperthermal entry conditions of advanced missiles and space vehicles. Commercially, electric arcs are widely used for illumination, metal cutting, flame spraying, and for other purposes. From a practical standpoint, arc technology has reached a rather high state of perfection, at least for arcs in static environments. However, for application to the generation of plasma jets, very little is known about the interaction phenomena between arcs and gasdynamic flow fields, with and without the presence of magnetic fields. The development of plasma jet generators has been essentially empirical, and the performance capability of such devices lags far behind requirements for simulating re-entry conditions of missiles and space vehicles. The complexity of the problem is fascinating, and many scientists and engineers have been lured to its study.

The Thermo-Mechanics Research Laboratory of ARL has initiated a systematic research program concerned with the fundamental interaction phenomena involved. In-house experiments are conducted on vortex-stabilized A-C arcs, high intensity D-C arcs, R-F plasmas, and various plasma diagnostic techniques. Many Air Force Institute of Technology students have participated in this program by performing investigations of specific aspects for graduate level theses. In addition, the program is supported and extended by a carefully planned series of related contract investigations.

AFCRL Notes

A detailed survey of the AFCRL research program has been published under the title, "History and Progress-For the Period January 1961-June 1962". Copies of the report are available from the following address: Research Information Office (CRI), Air Force Cambridge Research Laboratories, Bedford, Mass.

Twenty-nine Arcas Robin rockets were launched during a concentrated eight-hour period on 12 October from the Eglin Gulf Test Center. Purpose of the launches was to obtain fine-grain data on the variability of atmospheric densities and wind-velocities up to altitudes of 240,000 feet. Temperature and humidity were also measured. The Robin portion of the Arcas Robin combination consists of a one-meter inflatable balloon, enclosing an aluminized corner reflector for radar tracking. (Meteorological Development Laboratory)

Also on October 12, AFCRL fired an Aerobee rocket from White Sands Missile Range to measure the intensities and spectral distribution of albedo soft X-radiation from the lunar surface. The experiment was also designed to survey the sky for other possible X-radiation sources. The vehicle carried a 125-pound payload to about 155 miles. Information was telemetered to the ground. (Research Instrumentation Laboratory)

On October 23, also from White Sands, AFCRL launched another Aerobee to measure solar radiation between 250 and 1300 Angstroms in the extreme ultraviolet portion of the spectrum. The flight carried a photoelectric monochrometer to an altitude of about 135 miles. Information was telemetered to the ground. Recovery of the payload by parachute was made. (Space Physics Laboratory)

On October 24, AFCRL launched a three-stage Honest John-Nike-Yardbird combination from the Eglin Gulf Test Range to measure charged particle density and temperature in the ionosphere. The vehide and its 77-pound payload reached an altitude of about 277 miles. A Langmuir probe experiment, packaged in an eight-inch sphere was ejected from the rocket nose cone. The information was telemetered to the ground. No recovery of the nose cone was attempted. (Ionospheric Physics Laboratory)

new STELLAR OBSERVATORY

Ionospheric Physics Laboratory, AFCRL

AFCRL and the National Science Foundation have joined in plans for a new major observatory in the southern hemisphere. Heart of the new observatory will be a 60-inch reflecting telescope featuring a Coude (fixed position) focus. Barring unforseen problems, the observatory will become operational in mid-1964. The observatory will be located in Chile, although the specific site has not yet been selected.

A number of large optical telescopes have been built at good observational locations in the northern hemisphere. Few are located in the southern hemisphere. For observations of distant and faint objects in the southern sky, the world's astronomers are largely dependent on two 74-inch telescopes, one in Australia, the other in South Africa. Neither is completely satisfactory.

Two sites are presently most favored for the new telescopes. One of these, near Copiopo, Chile, about 500 miles north of Santiago, is located at a 10,200 foot elevation; the other, at a 7,300 foot elevation, is near Serurna, Chile, 300 miles north of Santiago. Plans for the southern hemisphere stellar observatory got under way in 1958 by AFCRL and the University of Chicago. Planning is now largely the responsibility of the Association of Universities for Research in Astronomy (AURA) which is supported by the NSF and which operates the Kitt Peak National Observatory near Tucson, Arizona. The southern hemisphere observatory will contain accessories that can be interchanged with those of major U.S. observatories, thereby enhancing the versatility of participating observatories. Most of the activity associated with the southern hemisphere observatory since 1958 has been devoted to a comprehensive site survey, with emphasis on astronomical "seeing". Obviously, the absence of atmospheric haze and cloud cover is desirable. But other atmospheric factors can seriously affect resolution and steadiness. Air Turbulence at all altitudes, diurnal temperature changes, and terrain features all influence seeing quality. The complex relationships of these factors are not properly understood or predictable. Because of the extreme care taken to find a site with optimum astronomical seeing, the new observatory will occupy one of the finest locations in the world from the standpoint of seeing sky transparency and absence of clouds. Observing time will be shared in an equitable manner among North and South American astronomers, including those of AFCRL and astronomers conducting research for AFCRL.

INSIGHT INTO ruby laser frequencies

Communication Sciences Laboratory (AFCRL)

Ruby laser crystals oscillate at many frequencies because of their large fluorescent line width. Techniques for examining these frequencies individually by means of optical fiber probes have recently been described by C. M. Stickley, R. C. White and R. A. Bradbury of AFCRL. Their analysis makes possible some interesting insights into ruby laser behavior.

The experiment developed by the AFCRL scientists uses an optical frequency discriminator (Fabry-Perot etalon) which separates the various frequencies in space. These frequencies occur at a fixed **separation** which is dependent on the length of the ruby rod. Optical fiber probes are then carefully positioned so that each of the fiber probes picks up the light from only one of these frequencies. The output of the probes are monitored electronically through the use of photo-multipliers and oscilloscopes.

When a laser is fired near its threshold, the brief flash lasts only about 200 microseconds. But during this time many things happen. It had previously been observed, for example, that oscillations at the various frequencies are intermittent -- that is, each frequency switches on and off during the brief firing. The experiment permitted the AFCRL scientists to analyze the switching pattern of various frequencies during each firing.

They found that although the total spike output (without frequency separation) appears similar from firing to firing, the frequency spectrum varies considerably. Oscillations that may be observed at one frequency during a firing may be completely absent at that frequency during the next firing. Statistical analysis shows that oscillations are more likely to occur at frequencies that are close to the peak of the fluorescent line.

It was found further that if there is oscillation at a given frequency on one side of the fluorescent line, there is a strong probability that the mirror image of that frequency on the other side of the line will not oscillate. The observed time dependent probability of the output of the laser at one of these specific frequencies appears similar to a damped sinusoid whose period is longer than the separation between adjacent spikes. The periods of the damped sinusoids for each of the modes are roughly the same.

These experimental observations do not agree with the simple concept of a inhomogeneously broadened line with holes burned in it at the

axial frequencies. Therefore, a more elaborate theory must be devised to explain the observed data. Since the firing level was controlled such that the total time that oscillation was detected was approximately 170 microseconds, thermal effects did not appear to have strong influence on the mode switching.

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